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085439**FINAL REPORT - NASA GRANT NAGW-4677**

Contract: NAGW-4677

Title: Very Large Array and Ratan 600 Observations in Support of the Coronas I Mission

Award Period: 06/01/95-05/31/96

During the award period of NASA Grant NAGW-4677, the world's two largest radio telescopes, the VLA and RATAN 600, were used to observe the Sun in support of the Terek Soft X-ray telescope aboard CORONA-I spacecraft, thereby enhancing the scientific return of all three instruments beyond that expected from using each one alone. The large collecting areas of these radio telescopes were uniquely suited for investigating quiescent coronal structures, and they each provided unique perspectives of high spatial resolution (VLA) and high frequency resolution with polarization (RATAN 600).

The research performed during this period built upon the following results of comparisons between the U.S. VLA and Russian RATAN 600 data.

1. Radio techniques for measuring the coronal magnetic field strength indicate that the million-degree corona above sunspots is 75 to 80% of that of the underlying photosphere.
2. Long-lived (hours to days) nonthermal, "peculiar" coronal sources, with high brightness temperatures and steep radiation spectra have been discovered.
3. Nonthermal noise storms, that can last for days, are apparently associated with large-scale coronal loops.
4. Nonthermal particles trapped within extended radio halos may serve as reservoirs to supply nonthermal "peculiar" sources and noise storms.

We have completed the proposed collaborative observations, using the combined data sets to localize regions of thermal and nonthermal energy release, and to specify their physical parameters. The astrophysical consequences of the research funded by NASA Grant NAGW-4677 include progress in the nature of particle acceleration on the Sun; mechanisms of continuous, nonthermal solar radio emission; the global, magnetic structure of the Sun's atmosphere; and possible heating mechanisms of the solar corona.

Combined VLA-RATAN observations indicate that the compact sunspot-associated sources lie at heights  $h = 2,500$  km to 17,500 km above the photosphere (Bogod *et al.*, 1995). The RATAN observations have been used with the theory of thermal cyclotron emission to infer magnetic field strengths in the million-degree plasma above sunspots of 75% to 80% of the magnetic field strength in the underlying photosphere (Lang *et al.*, 1993). The broad spectral-polarization coverage of the RATAN has been used to study sunspot-associated sources which exhibit reversals in circular polarization over relatively-narrow bandwidths (Willson *et al.*, 1995). Such changes have been attributed to a propagation effect through high-lying (about 200,000 km) quasi-transverse layers of the coronal fields with magnetic field strengths of 5 to 15 Gauss.

The processes that initiate and sustain nonthermal solar noise storms are not well understood, despite the fact that they are the most common type of radio activity on the Sun. Our combined VLA-RATAN-Spacecraft observations indicate that noise storms do not lie directly above the 20-cm or soft X-ray loops within individual active regions. They instead originate within large-scale loops that link widely-separated active regions, even in opposite hemispheres of the Sun (Willson *et al.*, 1995, 1997), or connect active regions to

more distant areas on the Sun. Our recent VLA - Spacecraft observations of noise-storm activity and evolving soft X-ray loops indicate that the radio storms may be triggered by large-scale magnetic interaction and/or particle propagation across magnetic loops that join active regions on opposite sides of the solar equator (Willson, Kile and Rothberg, 1997).

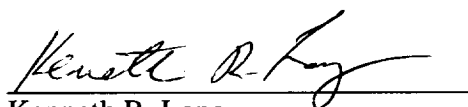
Noise storms are not always associated with the brightest active regions, and instead seem to be connected to active regions that have weaker thermal microwave emission and fainter thermal soft X-ray radiation than those associated with other visible active regions (Bogod *et al.*, 1995).

## REFERENCES

- Bogod, V. M., *et al.*, Solar Physics **160**, 133 (1995).  
Lang, K. R., *et al.*, Astrophysical Journal **419**, 398 (1993).  
Willson, R. F., *et al.*, Advances in Space Research **17**, 265 (1995).  
Willson, R. F., Kile, J. N., and Rothberg, B. Solar Physics **170**, 299 (1997).

## PUBLICATIONS RESULTING FROM NASA GRANT NAGW-4677

1. "Noise Storms and the Structure of Microwave Emission of Solar Active Regions", V.M. Bogod, V. Garimov, G.B. Gelfreikh, K.R. Lang, R.F. Willson and J.N. Kile, *Solar Physics* **160**, 133 (1995).
2. "Large-Scale Coronal Magnetic Fields: Noise Storms, Soft X-rays and Inversion of Radio Polarization", R.F. Willson, J.N. Kile, S. Donaldson, K.R. Lang, V. M. Bogod, G.B. Gelfreikh, B.I. Ryabov and S.R. Hafizov, *Proceedings of the XXX Committee of Space Research (COSPAR) Adv. Space Res.* **17**, 265 (1995).
3. "Radio Evidence for Nonthermal Magnetic Activity on Main-Sequence Stars of Late Spectral Type", Kenneth R. Lang, In: *Magnetodynamic Phenomena in the Solar Atmosphere* (eds. Y. Uchida, T. Kosugi and H.S. Hudson). Boston: Kluwer Academic Pub. 1996.
4. "Unsolved Mysteries of the Sun - Part 1", Kenneth R. Lang, *Sky and Telescope* **92**, 38 (1996) - August.
5. "Unsolved Mysteries of the Sun - Part 2", Kenneth R. Lang, *Sky and Telescope* **92**, 24 (1996) - September.
6. "VLA Observations of Interconnected Noise Storm Sources on the Sun", R. F. Willson, *Proceedings of the 9th Cambridge Workshop on Cool Stars, Stellar Systems and the Sun* (1996).
7. "Very Large Array Observations of Evolving Noise Storm Sources on the Sun", R. F. Willson, J. N. Kile, B. Rothberg, *Solar Physics* **170**, 299 (1997).



Kenneth R. Lang  
Professor of Astronomy  
Principal Investigator NASA Grant NAGW-4677